Before the

FEDERAL COMMUNICATIONS COMMISSION

Washington, DC 20554

Public Notice	)	
	)	
International Bureau Seeks Comment	)	IB Docket No. 17-172
on Implementing Earth Station Siting	)	
Methodologies	)	

To: Chief, International Bureau

COMMENTS OF
THE BOEING COMPANY

The Boeing Company ("Boeing") provides these comments in response to the Commission's Public Notice ("*Notice*") on the implementation of rules regarding the siting of individually licensed satellite earth stations on a protected basis in the 27.5-28.35 ("28") and 37.5-40.0 ("37/39") GHz bands.[1]

Boeing has strong interests in the growth of broadband satellite communications services in the 28 and 37/39 GHz bands. Boeing is a global leader in the design and manufacture of innovative satellite systems, including those employing millimeter wave ("mmW") technologies to provide very high data rate, low-latency communications services to all populations on a global basis. Boeing has requested Commission authority to launch and operate two non-geostationary satellite orbit ("NGSO") systems operating in the V-band in the fixed-satellite service ("FSS") and a third NGSO FSS system operating in the Ka-band.

The provision of very high data rate services can be accomplished by broadband satellite systems in mmW spectrum through the use of small spot beams and very high frequency reuse.

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1 *See* Public Notice, International Bureau Seeks Comment On Implementing Earth Station Siting Methodologies, IB Docket No. 17-172, DA 17-606 (June 21, 2017) ("*Notice*").

Boeing's NGSO FSS satellite systems will reuse each megahertz of spectrum thousands of times over through the operation of large numbers of satellites that will each produce hundreds or thousands of individual beams to serve end users. A separate gateway earth station will be needed in each region of the country for each reuse of the same spectrum. Thus, relatively large numbers of gateways will be needed.

Fortunately, Boeing can site these gateways in rural and remote areas where the upper microwave flexible use service ("UMFUS") is unlikely to ever be deployed. Boeing can concentrate its gateway earth stations in rural areas, however, only if the Commission eliminates its new restriction of three gateways per county or partial economic area ("PEA") and relaxes the 0.1 percent population restriction in rural counties and PEAs. For this reason, Boeing filed a petition for reconsideration of the Commission's earth station siting restrictions and Boeing urges the Commission to give these issues careful consideration.[2]

Concurrent with that petition, Boeing provided comments in the *Spectrum Frontiers* proceeding addressing the siting of satellite earth stations on a shared basis with UMFUS. Boeing reiterates and expands on those comments herein.

I. DEFINING A PFD CONTOUR OR PROTECTION ZONE THAT ACCOUNTS FOR ALL ANTENNA POINTING IS NECESSARY FOR FSS OPERATIONS

In the *Notice*, the Commission seeks comment on defining a "power flux density (PFD) contour" or, in the case of the 37/39 GHz band, a "protection zone" that takes into account any possible antenna pointing from an authorized earth station location.[3] Boeing strongly supports this approach as it is the most efficient and suitable method for the various types of FSS systems

[2] *See* Petition for Reconsideration of The Boeing Company, GN Dkt. No. 14-177, at 12-16 (Dec. 14, 2016).

[3] *Notice*, at 2, Section A item 1, and at 3, Section B, item 1.

that will operate in the 28 and 37/39 GHz bands. NGSO constellations by nature employ satellites in motion that transmit signals while transiting across the sky and require earth stations with agile "tracking" beams that are able to point in all directions of azimuth and maintain contact above various minimum elevation angles. Geostationary ("GSO") satellites are also spatially separated along the GSO arc, which stretches from the eastern horizon to the western horizon. Operators of multiple GSO satellites often employ the same co-located earth station sites to communicate with GSO satellites at multiple orbit slots, necessitating an unobstructed view across the entire GSO arc.

The PFD contour approach can capture the projected emissions mask in terms of PFD at a given distance from the "center" of the FSS earth station site using various pointing assumptions in terms of azimuth and elevation. When appropriately applied, the PFD contour approach can be simplified when necessary to a single radius, or it may also allow for cases in which the entire azimuth field of view might not be used (*e.g.*, a GSO-only earth station site). Similarly, for gateway earth stations receiving satellite signals in the 37/39 GHz band, a "protection zone" contour can define the projected region within which a given PFD level must not be exceeded by UMFUS devices, or within which certain types of UMFUS devices would not be allowed to transmit above a given EIRP density level. As discussed below, knowledge of the UMFUS device characteristics and operations would also be important in determining the appropriate contour levels and protection zone distances.

II. INTERFERENCE CONTOURS SHOULD BE COMPUTED USING REALISTIC CONDITIONS, WELL-DEFINED MODELS, AND SITE SPECIFIC INFORMATION

The computation of a PFD or "protection zone" contour appropriately involves the consideration of a number of factors regarding the communications link, some of which the

Commission has identified in the *Notice*; including a) the propagation model and conditions, b) the antenna patterns of the FSS earth station, and c) terrain and clutter models as well artificial shielding options.[4] Also important to these calculations will be the characteristics of UMFUS equipment, including UMFUS device antenna beams, their receive sensitivity (generally given by noise figure), transmit EIRP density (for the 37/39 GHz cases), and their relative antenna beam pointing. For example, in the case of the 28 GHz band, the Commission identified in the *Order* a PFD level that was based on numerous analyses provided by commenters on the general interference sensitivity of an UMFUS base station.[5] The level chosen by the Commission expressly accounted for the fact that the base stations employ narrow beams and beamforming techniques that result in the base station seldom pointing its peak beam gain towards the victim receiver, and is indicated as suitable for a variety of terrestrial interference cases into UMFUS equipment.[6] The *Notice* also requests information on clarifying the computation of the PFD levels using the propagation, FSS antenna gain, and localized terrain or shielding parameters.[7]

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[4] *See id.* at 2, Section A, item 2.

[5] *See* Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177, *Report and Order and Further Notice of Proposed Rulemaking*, FCC 16-89, ¶ 312 (Jul. 14, 2016) ("*FNPRM" or "Order*").

[6] *See id.*, ¶ 294 (acknowledging the dependencies and potential reductions in interference based on "features such as antenna downtilt, suppression, of sidelobes and adaptive power control") *see also id.*, ¶ 312 (observing that "Intel's proposed PFD was based on *worst case assumptions* about the receive antenna gain" and subsequently concluding "[w]e believe that this assumption is *overly conservative*" and further observing that a coalition of UMFUS advocates stated that "a lower antenna gain is typically computed in the simulation towards the earth station since the receive beam is pointed in the direction of the transmitting UE, and it is *statistically unlikely* to coincide with the direction towards the earth station") (*emphasis added*).

[7] *See Notice* at 2-3, Section A, item 2.

A. PFD Contour and Protection Zone Calculations Should use Available Published Propagation Models from the ITU and Recognized Standards Bodies such as 3GPP

In the *Notice*, the Commission seeks comment on which propagation models and conditions should be used to compute a Ka-band PFD contour, and a similar request is made regarding the propagation models to be used for a V-band FSS earth station protection zone.[8] This request echoes a similar request for comment that was included in the *Spectrum Frontiers FNPRM*.[9] Consistent with Boeing's *FNPRM* comments,[10] Boeing recommends that any propagation calculations needed for computation of PFD contours be based on the most current in place ITU models governing terrestrial propagation. These models, which take into consideration atmospheric effects, rain, and terrain/clutter, benefit from a large body of work including propagation studies and extensive measurement campaigns, with coordination and review by all members of the ITU Radio Propagation working group. To augment the ITU standards work, Boeing recommends that the integrated line of site ("LOS") and non-line LOS ("NLOS") propagation models from the 3G Project Partnership ("3GPP") also be used to derive contour values.

Although the resources listed above are essential to the computation of PFD contours, the fundamental question remains regarding whether a single propagation model should be used to determine the contour boundary; and, if so, which model should be used? Throughout the *Spectrum Frontiers* proceedings, numerous parties presented analyses of PFD levels generated

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[8] *See id.* at 2, Section A, item 2.a and at 4, Section B, item 2.a.

[9] *Spectrum Frontiers FNPRM*, ¶¶ 511, 512, and 513.

[10] See Appendix A, propagation model recommendations from Boeing's *FNPRM* Comments.

by an FSS earth station.[11] These results all included significant variations in the resulting PFD level that would be received at a given distance, which was often a function of the propagation model that was used. Therefore, further work is needed to ensure that appropriate propagation models are employed and the factors that they consider result in realistic determinations regarding the actual sharing conditions that exist between satellite earth stations and UMFUS systems.

B. PFD Contour and Protection Zone Calculations Should use Proposed Earth Station Antenna Models or Data Rather Than Generic Compliance Masks

In the *Notice*, the Commission seeks comment on the modeling of antenna patterns and antenna gain, with options ranging from pre-specified angular masks (which apply in the far-field) to near-field modeling of aperture field distributions.[12] In general, Boeing does not recommend using a pre-specified far-field antenna mask, such as those used in Section 25.209 for GSO or Ku-band FSS earth stations. The continuous and on-going evolution of antenna technology will likely enable implementations that differ markedly from the current antenna masks in ways that may be highly relevant to the calculation of the PFD contours for the 28 GHz band or the protection zones for the 37/39 GHz band. It is in the best interests of all parties – including satellite and UMFUS licensees, and consumers of these services – to rely upon a more accurate representation of the actual operation of FSS earth stations and UMFUS networks. Boeing therefore agrees with the Commission's suggestion and recommends that FSS earth station applicants should be allowed to demonstrate the potential PFD contours or protection

[11] *See, e.g., Joint Filers Letter* at 1; *Sharing between FSS and 5G Systems at Frequencies Around 28 GHz*, Intel Corporation, at 7 (June 21, 2016), *included as attachment to* Letter from Peter Pitsch, *et al*., Intel Corporation, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177 *et al.* (June 21, 2016) ("*Intel Study*").

[12] *Notice* at 2, Section A, item 2.b, and at 4, Section B, item 2.b.

zones through computations using simulated and/or measured antenna patterns.[13] This approach can minimize the extent of the interference contours, serving the best interests of FSS and UMFUS licensees, as well as consumers.

With regard to antenna modeling, the state-of-the-art is well-defined in both the literature and various public-domain software programs. Simulated antenna pattern results presented by earth station applicants should be reviewed by the Commission for general agreement with expected results from such programs, as well as the relevant earth station gain masks and other OET technical memoranda. When proposing the distances for PDF contours or protection zones, the antenna gain patterns should be predicted or measured using the appropriate methods that are cognizant of the near-field and far-field field densities and equations. As pointed out in Boeing's *FNPRM* reply comments,[14] many of the analyses presented in the *Spectrum Frontiers* proceeding, both prior to and following the issuance of the *Order,* used the Fris equations and classic far-field antenna pattern coupling analyses, which are only valid in the far-field. Measurements presented in the *FNPRM* proceeding of actual earth stations were taken at distances in the 100-200 meter range and the parties that took those measurements attempted to use Fris equations and classic far-field antenna patterns to predict results, without taking into account the near-field effects present within the Fraunhofer distance of ($k*D^2/\lambda$).[15] FSS gateway earth stations typically employ large apertures to provide high rain availability while

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[13] *See id.* at 2, Section A, item 2b.

[14] Boeing FNPRM Reply Comments at 29-30.

[15] *See, e.g.,* Letter from Jeffrey A. Marks, Government Relations, Nokia, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177, *et al.*(Oct. 20, 2016), Attachment 2, "Measurements of Fixed Satellite Service (FSS) Earth Station Spillover Emissions to Evaluate Potential Interference Levels to Nearby 5G Systems Operating in the 28 GHz Frequency Band" (Oct. 18, 2016).

supporting the wide bandwidth and distances required for feeder link communications with NGSO and GSO satellites. Far-field distances can range from 500 to 1,680 meters depending on the aperture size and frequency. Therefore, it is important that correct modeling and measurements, using calibrated equipment with the necessary field density and distance translations correctly applied to the results, be used if PFD contours or protection zone distances are proposed that exist within the near-field range of the earth station apertures.

C. PFD Contour and Protection Zone Calculations Should Take into Account Proposed Shielding and/or Terrain Features as part of the Estimated Interference Levels

In the *Notice*, the Commission seeks comment on whether the effects of terrain and natural or artificial (man-made) clutter should be taken into account, rather than use a "general" propagation model.[16] Boeing identified in the previous section of these comments various standard terrain and clutter models, as well as 3GPP propagation models, that include a general NLOS effect on the propagation of the signal. Boeing recommends that these general propagation models are sufficient for the initial definitions of PFD contours and protection zone values that would be submitted by FSS earth station license applicants.

Computing the potential PFD at a given distance at a height of 10 meters, over 360-degrees of azimuth, using terrain contours, ground reflection and scattering, and physical object material properties and their scattering and reflections for every proposed FSS ground station location would be a daunting prospect. As Boeing has demonstrated through extensive modeling, the use of buildings and clutter can provide effective natural shielding for direct LOS

[16] *Notice* at 3, Section A, item 2.c, and at 4, Section B, item 2.c.

propagation into UMFUS receiver locations.[17] Boeing has also recommended, however, that UMFUS site information (in particular, base station locations, and possibly specific CPEs located closer to the FSS earth station site) should also be allowed to be considered in the demonstration analysis. Such information would enable an FSS earth station applicant to take into account the more specific scattering and blockage effects of terrain and clutter between the FSS earth station and actual UMFUS equipment locations.

Finally, there are specific implementations of FSS earth station sites, such as on top of wide, tall buildings, or adjacent to cliffs or hillsides, *etc.*, where terrain or blockage information would be simpler to model. Boeing's recommendation to include general propagation model information in all applications is not meant to preclude applicants from including such information in PFD contour or protection zone calculations for these special cases.

The Commission also requests comment in the *Notice* regarding whether the effects of artificial shielding of the FSS earth station should be allowed to be included in the PFD contours submission.[18] Boeing recommends that such shielding be permitted and it should be taken into consideration for PFD contour calculations. Shielding of transmission equipment can be an effective method of attenuating emissions both in the near-field and far-field, potentially over a broad range of azimuths and at low elevation angles and heights. The use of shielding, however, must be optional and defined as needed by the applicant due to the wide variety of potential FSS

[17] *See* Boeing *FNPRM* Reply Comments at 13-17; Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177, *et al.*, at Attachment 2 (June 29, 2017) (providing extensive analysis of the effects of multipath and natural shielding in calculating satellite emissions into UMFUS); Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177, *et al.*, at Attachment 2 (May 15, 2017) (same).

[18] Se *Notice* at 2, Section A, item 2.c.

earth station antenna implementations and their various pointing solutions (*e.g.*, gimbaled mechanical dishes versus electrically steered arrays for NGSO systems, *etc.*). In addition, shielding may be less effective as a mitigation technique with respect to protecting earth station receivers from UMFUS emissions in the 37/39 GHz band, particularly given the unknown nature of the locations of transmissions from UMFUS end user devices. Since it currently appears unlikely that operators of UMFUS base stations would commit to shielding in the direction of FSS earth stations, Boeing believes that the FSS earth station protection zones in the 37/39 GHz band will likely need to be defined initially by the earth station applicant without the benefit of any artificial shielding.

III. ADDITIONAL CONSIDERATIONS FOR V-BAND PROTECTION ZONES

In Boeing's comments above, we have responded to the Commissions questions in the *Notice* in a general way that addresses many of the common issue raised by the *Notice* that may apply to FSS earth stations in both the 28 GHz and the 37/39 GHz bands. It is important to note, however, that although many of the questions raised are common to both frequency ranges (particularly regarding such considerations as propagation, antenna gain, *etc.*), the interference situations are not perfectly reciprocal or identical.

For FSS earth stations in the 28 GHz band, the FSS earth station is transmitting and the affected area – called a "PFD contour" – measures the emissions of the earth station that can affect a potential UMFUS victim receiver. For FSS earth stations in the 37/39 GHz band, the FSS earth station is receiving satellite signals and the affected area – called a "protection zone" – is where FSS earth station sites would be protected from UMFUS interference.

The Commission determined in the *Order* that a PFD level of -77.6 dBW/m2/MHz would be sufficient to manage the interference effects into various UMFUS receivers in the 28 GHz band.[19] The Commission, however, did not identify an equivalent level of protection for FSS earth stations in the 37/39 GHz band due to the wide variety of possible earth stations sizes and satellite signals being addressed. Therefore, each FSS earth station applicant seeking to operate in the 37/39 GHz band must define the fundamental interference level that is tolerable at its earth station site in order to generate a protection zone boundary contour using any of the methods discussed above.

As a consequence, the Commission seeks comment in the *Notice* regarding how the Commission should evaluate "the reasonableness of the protection criteria the applicant uses in its computation of the protection zone?"[20] A common method of defining tolerable interference uses the interference-to-noise ratio ("INR"), or noise floor increase in dB at the FSS receiver due to the interfering UMFUS services. INR values of -10 to -6 dB, with noise floor increases of 0.5 to 1 dB, or up to 12-25 percent, were discussed in various contexts throughout the *Spectrum Frontiers* proceeding. Further, there is significant material in the *Spectrum Frontiers* proceeding regarding the computation of the noise floor using worst-case versus statistical values for the UMFUS equipment EIRP, locations, and beam pointing directions.

As Boeing has explained previously, a statistical model is generally best suited for calculating the interference levels for a system with mobile users and time-varying beam pointing characteristics. The limited number of FSS earth stations that will receive protection from UMFUS transmissions will invariably be used as gateway stations, which require a very high degree of availability and confidence that transmissions will not be degraded. Satellite gateways provide the "feeder" links that serve and directly impact all end users of FSS services.

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[19] *See Spectrum Frontiers Order*, ¶ 312.

[20] *Notice* at 4, Section B, item 2.a.

Therefore, although statistical results for UMFUS interference should be computed in determining protection zones, it is appropriate to also perform a worst case analysis to capture UMFUS use cases such as fixed-location (non-mobile) bi-directional links from CPEs to/from base station links.

Likewise, since the *Order* did not mandate the use of beamforming and power control for UMFUS equipment, such worst case analyses may also need to assume the receipt by the victim earth station of the maximum EIRP density from UMFUS devices, with limited beamforming directional isolation capability, unless these issues are subsequently addressed by the Commission on reconsideration. Such conservative definitions for protection zones would not serve the public interest. Instead, Boeing urges the Commission to use this proceeding to gather data that might define acceptable limits on individual maximum UMFUS PFDs, and aggregate UMFUS PFD emissions (which would be analogous to the PFD level specified for the 28 GHz band) that FSS operators would have to design their earth stations to tolerate. Such an effort would make the computation of protection zones for the 37/39 GHz band more uniform across various types of potential FSS earth stations.

IV. DETERMINING POPULATION PERCENTAGES WITHIN CONTOURS

In the *Notice*, the Commission seeks comment on the level of detail that should be used to determine the percentage of the population that may be affected by a PFD contour or protection zone within each county or PEA.[21] Boeing recommends that the earth station applicant be permitted to use the most recently published U.S. Census Bureau information. Boeing also recommends that applicants be permitted to use the census block group database, which is the smallest geographic area that has assigned population data from the Census Bureau.

[21] *Notice* at 3, Section A, item 3 and at 4, Section B, item 3

For contours overlapping the various block groups, the "actual area method" (*i.e.*, the ratio of the area of the block lying within the contour multiplied by the total population of the block) would be used to determine the affected population.

V. CONCLUSION

Boeing provides these recommendations in order to maximize the ability of operators of broadband satellite systems and UMFUS networks to intensively share the 28 and 37/39 GHz bands in order to use mmW frequencies to provide very high data rate broadband services to all Americas and globally. Although the points raised by Boeing in these comments are important to facilitate robust spectrum sharing, their value to enhancing the potential for sharing will be exceedingly limited without further action by the Commission to relax its earth station siting restrictions for FSS systems in the 28 and 37/39 GHz band in non-urban areas of the country.

Respectfully submitted,

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ATTACHMENT A
COMMENTS ON PROPAGATION MODELS
(FROM BOEING'S FNPRM COMMENTS)

Propagation modeling for FSS and Terrestrial Systems: The Commission seeks comment on which propagation loss models (*e.g.*, Close In ("CI") and/or alpha-beta-gamma ("ABG")), and their associated measured data, would be the most appropriate to use when analyzing inter-service interference between terrestrial-based transmitters and victim receivers of different services. Boeing uses a form of the CI model that requires a single path loss exponent ("PLE") and a frequency-dependent constant to define the path loss equation. To determine the PLE, Boeing relies upon the following sources of measured propagation information:

[1] "38 GHz and 60 GHz Angle-dependent Propagation for Cellular & Peer-to-Peer Wireless Communications", Rappaport et. al., IEEE ICC 2012 - Wireless Communications Symposium.

[2] "Millimeter-Wave Omnidirectional Path Loss Data for Small Cell 5G Channel Modeling", IEEE Access Journal, SPECIAL SECTION ON ULTRA-DENSE CELLULAR NETWORKS, September 2015.

[3] "Millimeter Wave Channel Modeling and Cellular Capacity Evaluation", Akdeniz and Rappaport, IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, VOL. 32, NO. 6, June 2014.

[4] "Channel model for frequency spectrum above 6 GHz (Release 14)", 3GPP TR 38.900 V14.3.1 (2017-07).

Boeing's modeling typically selects the most appropriate of these propagation models to determine the NLOS losses expected in each environment. When using NLOS conditions, we select the appropriate model using guidelines described below.

a) <u>Rural Macro NLOS losses</u>: In rural conditions reflecting a lightly cluttered terrain model and a taller base station, Boeing utilizes the PLE derived from references [1] and [2] based on measured data at the UT-Austin campus. The 3GPP Rural Macro model in reference [4] allows the effective PLE to vary from 2.3 to 3.2 over a very short distance, reflecting greatly increased clutter that was not found during measurements in reference [1].

b) Urban Macro or Urban Micro NLOS losses: Boeing uses and recommends the use of the 3GPP channel modeling losses described in reference [4] for Urban Micro and Urban Macro conditions. The optional model for these contains PLE=3.0 which is aligned with NUY measurements exhibiting PLE=3.1. Occasionally, Boeing may apply PLE=3.4 to 3.7 in these cases to determine dense urban street corridor losses.

c) Outdoor-to-Indoor penetration losses: Boeing primarily analyzes interference effects on receivers operating outdoors, as satellite downlink signals are unlikely to penetrate indoor regions, and any satellite uplink signals sharing a propagation path will experience nearly identical fading once the signals enter the same building. Boeing, however, does use the 3GPP channel modeling report [4] outdoor-to-indoor loss recommendations when modeling the EIRP necessary for 5G devices (particularly, base stations) to overcome losses for the users located in these conditions.

Overall, it is Boeing's conclusion that the CI model is accurate and representative of NLOS path losses. Boeing uses this model and selectively chooses the most appropriate approximate PLE that matches available data from the relevant frequency and environment. In addition, in order to fully understand the interference limits, Boeing routines uses clear LOS as a minimum bound for path loss. Although this case is rarely realistic except for short ranges, it provides a convenient check for other conditions.

Rain loss modeling for FSS and Terrestrial Links: Modeling of additional losses due to weather and rain is required to understand certain interference situations, particularly those involving power control. As noted previously in these comments, Boeing uses the most recent ITU recommendations, in particular ITU R.618-12, to compute weather and atmospheric related propagation losses for satellite links.[22] Similarly, Boeing uses a series of ITU Recommendations (ITU P.837, ITU R.P.530-13, and ITU R.P.838-3) to compute the rainfall rates and rain attenuation for terrestrial links and the propagation paths between FSS earth stations and 5G UMFUS devices.[23]

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[22] ITU R.618-12, "Propagation data and prediction methods required for the design of Earth-space telecommunication systems", July 2015

[23] ITU-R P.837-6, "Characteristics of precipitation for propagation modeling", Feb 2012 ITU-R P.838-3, "Specific Attenuation Model for Rain for Use in Prediction Methods", Mar 2005 ITU-R P.530-16, "Propagation Data and Prediction Methods Required for the Design of Terrestrial LOS Systems," July 2015